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ABSTRACT

As part of attempts to find out why few high school science students take Physics 12, this case study sought University of British Columbia (UBC) science teacher educators' perspectives on the topic. A survey method employing questionnaires and interviews as part of the study was used to elicit science teacher candidates' perspectives. Forty-five teacher candidates participated. From those who participated in the questionnaire part of the study, 19 were interviewed as a way of clarifying their questionnaire responses. Several points emerged from the study in the form of inferences, which are considered significant to the inquiry question and the preparation of preservice physics teachers as well as the teaching of physics in general. Results indicate that mathematics is a very important tool in physics and imply some points to physics teaching. (KHR)

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The status of Physics 12 in BC: Reflections from UBC science teacher candidates

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Many high school science students in the Province of British Columbia (BC) take Chemistry or Biology 12 rather than Physics12. This is evident from the participation rate ratio of physics: chemistry: biology as 1:1.5:4 (2:3:4) in the provincial examination (BC Prrovincial Standard Report 5015B) for the last six years (1996 – 2002). As part of attempts to find out why few high school science students take Physics 12, a qualitative case study employing questionnaire and interview procedures sought UBC science teacher candidates' perspectives on this. They reflected on their own high school experiences as former high school students by explaining what might have attracted them to or prevented them from taking Physics 12 or continuing with physics. Analysis of questionnaire responses revealed mathematics phobia, the physics teacher, the nature of physics activities and prior experience and knowledge in previous foundation physics courses as among the key factors, which influenced their decisions concerning majoring or furthering in physics.

More factors emerged from follow-up face-to-face interviews. From the interviews, counselors were cited as "wielding" great influence on students' course choices. Other revelations included: the gender factor, physics teachers' assumptions of students' prior knowledge of mathematics, when the quantitative aspects of physics are introduced and study skills. This paper considers the counselor factor a derivative of the other factors, which are categorized as: *mathematical*, *instructional*, *nature of physics activities* and *role model* factors.

It is also argued in this paper that physics teachers should take full responsibility for the instruction of physics, which must include "sharpening the tools of physics", e.g., mathematics, by providing remedial lessons. In addition, teachers need to rethink their instructional approaches, and this paper strongly recommends teaching styles that are informed by constructivist theories of learning. The importance of students' prior knowledge, which must include mathematical competencies, is underscored. This knowledge should be considered when planning instructional activities. The Predict-Explain-Observe (PEO) type of activities (Gunstone, 1994) are also highly recommended because of their potential to elicit students' preconceptions, which according to Kelly (1955), influence how students (learners) interpret and understand new information or experience.

A "School Physics Instructional Model" (SPIM) is proposed as one of the tools for instruction that can assist in the planning and implementation of appropriate teaching and learning activities in physics.

Theoretical Framework

How high school physics curriculum is organized and taught impacts the way the would-be Physics 12 students perceive the subject and its content. Perhaps the question here is: what counts as physics education? This question resonates with a similar one raised by Hodson (1998) about what counts as science education. Whether the question is asked of physics or science education in general, it will certainly attract a variety of responses. Different stakeholders (students, pre-service and in-service teachers, curriculum designers, etc) might respond differently to this question. According to Hodson (1998), for some, science education is about the selection, training and education of future scientists and professionals in science related fields. For others, it is about being assured of employment, and for others still, it is about preparation for responsible citizenship. Those who have already been through the system (qualified physicists, chemists and biologists or physics, chemistry and biology related professionals) can provide some insights into what it is that attracted them to or prevented them from majoring in physics since they are studying to become science teachers in high schools.

Weizsacker and Juilfs (1957) cite Michael Faraday as defining physics simply to be " make experiments and publish them"(p.11). But, they expand on this definition by viewing physics to be " rooted in the experiments, in active, inquisitive and skillful intercourse with the nature" (p.11). In addition, Weizsacker and Juilfs have underscored the role mathematics plays in the teaching and learning of physics concepts, saying: "The tool of conceptual thought in physics is mathematics for physics treats of the relations between measured, that is numerically determined " (p.11). Elaborating on this statement, they reckon two components of physics: *experimental* and *theoretical*. They see the theoretical component as including mathematical (quantitative) aspects.

It is no wonder that some physics teachers take this view and apply it direct in their physics instructions. In fact, mathematics is such a major component of physics to a point where without it; no meaningful understanding of physics can be claimed. Thus, special attention must be given to the mathematical knowledge and skills that students bring to physics learning situations. Also, since mathematics is the tool of physics it is incumbent upon physics teachers to ensure that their physics students are prepared through remedial in the mathematics appropriate to physics topics intended for instruction. According to Weizsacker and Juilfs (1957), a physicist is " expected to give a reasoned answer to every new technical question by applying his [/her] knowledge of the fundamental laws of nature" (p.11).

Furthermore, mathematics has been seen, since the Newtonian mechanics era, as an essential component of conceptual understanding in physics. Kline (1980), reflecting on the Newtonian mechanics says: "Mathematics was not just an aid to physics in the sense of convenience, briefer, and more general language; rather it provided the fundamental concepts" (p.57).

Physics as defined by Weizsacker and Juilfs (1957) studies nature. Thus, "the Newtonian scheme is decisive in convincing the world that nature is mathematically designed and that the true laws of nature are mathematical" (p.57). This statement appears to reveal the complex marriage between physics and mathematics. However, this view has not gone without criticism for implying the existence of universal orderliness that must be discovered (Dellow, 1970). Furthermore, the evolving area of chaos theory (Duit, Komorek & Wilbers 1997, 1998) appears to challenge the view of the orderly nature of things or events in the universe. But what else might the statement convey in terms of physics instruction? It probably underscores the need to ground potential physics students in mathematics. Poor understanding of mathematics is likely to impede a student's deeper understanding and appreciation of physics. Bridgman (1961) has further underscored the role mathematics plays in physics:

> Practically all the formulations of theoretical physics are made in mathematical terms . . . It is then evidently pertinent to consider the nature of the mathematics to which we assign so prominent a role ( ) [It] is the merest truism, evident at once to unsophisticated observation, that mathematics is a human invention (p.60).

Perhaps a human invention in the sense that it is a tool of conciseness which physics employs – one that we must equip our potential physics students with to enable them to solve natural phenomena problems in the most efficient manner; one without which understanding of physics can be hampered.

Another probable factor influencing high school students' perceptions of physics education to the point of say, wanting or not wanting to continue with the subject beyond Physics 11 is the way they experience learning the physics. It has been determined and argued that learning is most likely to be meaningful when the resulting knowledge gets personalised (Hodson, 1998; Polanyi, 1962), which is largely an issue of instructional styles among others. For example, a class, a subject, instruction or content in which learners' prior knowledge is recognized and appreciated (Dobrin, 1997; Driver, 1983, 1989), whether the knowledge is acceptable to science or not, may be considered attractive to many students. In one-way or the other, prior knowledge impacts the learning of new subject matter as Kelly (1955) has eloquently put:

> All thinking is based, in part, on prior convictions. A complete philosophical or scientific system attempts to make all these prior knowledge explicit (p.6).

However, not all prior knowledge is necessarily of scientific importance. But recognizing and challenging it meaningfully – by deliberately providing experiences aimed at providing the challenge, will get them into the state of starting to question their initially held beliefs and ideas, and perhaps begin to seek or search for more satisfactory answers.

Several studies, some of which are discussed below, have in one way or the other attempted to bring to the fore some of the key factors that are likely to affect students' decisions regarding subject choices. These factors include: *teacher attitudes, beliefs and practices; Students' beliefs and study skills; and student advisors (counselors).*

Some key studies

As mentioned above, there are many studies done in this area of student choices. However, the ones discussed below are only a representation and they function as anchors to the current study by providing an insightful lens through which data from the current study has been examined. This is an attempt to discern factors that affected the participants' decisions regarding pursuance of physics beyond basic introductory courses when they were high school students.

Teacher attitudes, beliefs and practices

A study by Behar-Horestein, Pajares and George (1996) determined that, teachers' beliefs affect students' academic performance after comparing their performance before and after a curriculum innovation (see also Lumpe, Haney and Czerniak, 2000). The teachers, in an interview as part of the study complained for not having been consulted before curriculum changes were introduced. They expressed pessimism about the success of the innovation. As a consequence, there was no change in the students' mean grade despite their (students') liking of the innovation. The study reports how displeased the students were with the grades under the new curriculum, charging the teachers with neglect and inattention to their needs. In one way or the other issues discussed in this study most likely can impact the way a student sees a subject that might be most affected by curricula changes - similar to those noted by Behar-Horestein et al.

Adams and Salvatera (1998) conducted, which examined the necessities for successful block scheduling in high schools. The study revealed that many a times the structural and programmatic changes in scheduling were unaccompanied by changes in the individuals (teachers). Adams and Salvatera concluded that static teacher behaviour limited the effectiveness of the broader organizational changes. It simply means that any changes affecting the curriculum should be matched by changes in teacher behaviour. Otherwise, as the Behar-Horenstein et al. (1996) study shows that if the teachers' attitudes and beliefs do not change consistent with curricular or programmatic changes, there is a high probability of the new program failing. And this, in turn could affect the students' attitudes towards subjects most affected by the change.

Students' prior knowledge and beliefs about studying

Gore (1988) while on a promotion of a "science show" got surprised by the level of interest shown in the science activities at the show, which he intentionally presented along side the arts activities. However, of significance to the current study is the question he raised arising out of a long teaching experience:

> Have you ever noticed that junior secondary students always think they know what biology and chemistry are, but seldom know what physics is? (p.8).

Although this was not a study *per se*, the question raised is a troubling. The message in Gore's question is very important and worth the attention. If students cannot know what constitutes physics then surely a rethinking of teaching approaches is required – one that can provide them with an understanding of what physics is.

Jones, Slate, Blake and Sloas (1995) carried out a study, which revealed a correlation between students' view of intelligence and academic study skills. Using the "Study Habits Inventory-High School and Thoughts about Achievement Scale", they determined that the students who held the incremental view of intelligence scored higher on the scale across the grades than those who held the entity view of intelligence. These findings are of interest to the current study since it is after grade11 physics that students in BC high schools decide on Physics 12. If academic study habits involve memorization then obviously such students should find Physics 12 content overwhelming and might get scared of it. Jones et al. study seems to call on teachers to pay special attention to study skills early enough.

Norvilitis, Reid and Norvilitis M. B. (2002) conducted a study that examined factors that enhance success in everyday physics. They concluded that everyday performance on the physics quiz had a strong relationship with physics grades achieved previously, highest level of math taken and students' perceived scholastic competence. This too has implications on the decisions students have to make regarding subject choices. In other words, their prior experiences in introductory physics courses, which include performance does have direct effect on the choices they may make. Certainly as the ongoing discussion indicates mathematics seems to be emerging as a key factor in physics related decisions. That is, the highest level of mathematics taken means students come to physics with a good repertoire of mathematical competencies from which to draw. In other words, competency in prior mathematical knowledge most likely will be an advantage to a potential physics student, hence the development of a higher affinity for physics.

Instructional styles

Roth, MacRobbie, Lucas and Boutonne (1997) determined in their study why students might fail to learn from demonstrations. They revealed six dimensions that impede or obscure students from making sense of demonstrations: lack of a theoretical framework to separate signals – the phenomena – from noise; interference of discourses learned in other contexts of the physics course; interference from other demonstrations and images that had some surface resemblance; low salience of knowledge related to demonstrations on tests; students' problems in piecing together coherent representational frameworks from the information given; and lack of opportunities for students to test their descriptions and expectations. Students experiencing these states of affairs most likely will drop out of physics course(s) at the earliest permissible opportunity.

Snyder (1998) conducted a study that determined that interviewing students through problem solving is an effective means of evaluating them and their special needs; and, that setting time for this provides the teacher with opportunities to understand individual students and diagnose specific learning problems. Questioning students through a problem solution more likely promotes understanding, a factor implied in Jones et al.'s (1995) study. This could be a skill worth investing time by physics teachers. Of course, problem solving utilizes mathematical knowledge and skills, which Weizsacker and Juilfs (1957) consider being a tool of physics. In any case, problem solving and mathematics seem to have an inseparable marriage. Again, the experiences students get from problem solving situations can impact their decisions regarding subject choices, and certainly physics will not be an exception.

Graber (1998) investigated the influence of teacher education on a high school teacher's instructional behaviour. The study was about monitoring the instructional behaviour of a high school teacher in her third year of teaching physical education. Although the focal subject is different, the findings are relevant to the current study. Graber's study revealed that student teaching was the means by which this teacher predicted the difficulties she carried into induction. It was further revealed that being provided with the principles of good teaching does not necessarily mean being equipped with the operations for effective teaching behaviour. The findings of this study can lead to pertinent and challenging questions such as: Do student teachers get enough practice to match the theory they receive while in teacher education programs? Is 9 – 12 months of teacher education enough? Do we need to do more training than educating? The study is a useful one because it points out some of the qualities teacher educators need to cultivate in student teachers before they get "absorbed" into teaching.

Sherin (2001) has underscored the need to teach physics for understanding. This comes as a result of a question he posed regarding the meaning of understanding a physics question. He reiterates the need for understanding by saying:

> The use of formal expressions in physics is not just a matter of the rigorous and routinized application of principles, followed by the formal manipulation of expressions to obtain an answer. Rather, successful students learn to understand what equations say in a fundamental sense; they have a feel for expressions, and these guide their work (p.479).

Analyzing video data corpus of university students solving physics problems, Sherin concluded among other things that students many a times viewed a particular arrangement of symbols in a question as expressing a particular meaning; that physics students understand physics equations in terms of vocabular elements or symbolic forms. These findings too have a bearing on the current study since understanding of mathematics does propel the students to develop an affinity for physics. In other words, prior efficiency and competency in mathematical knowledge and skills and experience in prior physics activities most likely will impact their decisions regarding the pursuance of physics beyond introductory courses.

Student advisors

Wilson and Rossman (1993) reveal that counselors are the ones who slot students into programs they deem suitable for them (students). This study touches on what the current study is looking into: what influences students' decisions to major in some subjects and not others. Certainly, counselors must have a role to play on how students make subject/course choices - such as Physics 12.

The above factors are in a way mirrored by those emerging from the current study.

The Study

The inquiry, which involved science teacher candidates in the Teacher Education Program (TEP) at UBC, is an intrinsic qualitative case study (Stake, 1998) into the perspectives of UBC physics, chemistry and biology teacher candidates on why they took/ continued with or did not take/continue with Physics 12. From their responses factors, which influenced their decisions, were discerned, and from these the case of factors affecting BC high school students' decisions on Physics 12 are inferred.

A survey method employing questionnaire and interview as part of the study was used to elicit the candidates' perspectives. Forty-five (7 physics and 38 chemistry/biology) teacher candidates participated. From those who participated in the questionnaire part of the study, 19 indicated a willingness to be interviewed (Fontana & Frey, 1998) as a way of clarifying their questionnaire responses. This part of the study comprised four open-ended items for each category of the teacher candidates.

Physics teacher candidates:

- *Why did you choose Physics 12 at high school?*
- *What specifically attracted you to major in physics at high school and beyond?*
- *What in your view prevented your colleagues from taking Physics 12 or continuing with physics?*
- *What would you have liked to see done differently that could have made your peers, who did not take Physics 12 or did not continue with physics to take it?*

Biology/chemistry Candidates:

- *Why didn't you take Physics 12 at high school? Or if you did, at what level did you stop taking physics and why?*
- *What was in biology/chemistry that was lacking in physics at high school?*
- *What role did (a) content (b) teaching style play in your decision not to take Physics 12/not to continue taking physics?*
- *What would you have liked to see done in physics that could have influenced your decision to take Physics 12 at high school/ continue taking physics?*

Initial "surface" analysis (Miles & Huberman, 1994) of responses to these items revealed several factors that were further probed through interviews with some of the participants.

Results

Analysis of questionnaire responses revealed several factors the following:

1. Mathematics
2. The physics teacher and instructional styles
3. The nature of physics content and activities
4. Model female physics teachers
5. Method of studying physics
6. Prior experience from previous introductory physics courses

Mathematics, as portrayed in the literature, emerged as a very important factor in the learning of physics. Some teacher candidates owed their success in physics to their understanding of mathematics. Others, of course blamed their disinterest in physics to mathematics, as the following excepts attest:

"I was interested in the math and problem solving in geometric optics."
"Some of my friends did not like mathematics hence physics also."
"I enjoyed problem solving and anything that was thought to be difficult."
"I was afraid there would be learning of equations."

The physics teacher

The "physics teacher" was portrayed as some one who could inspire students to like physics. Also, this teacher was portrayed as someone who could drive students away from the physics subject as conveyed in the following representative statements:

"My high school had good physics teachers and program."
"My physics teacher was not passionate about it and did not teach us."
"I did well though my teacher was not particularly good. All we did in physics 11 was copy notes and solve text problems. There were no hands-on activities."
"My physics 11 teacher was so bad that I could not put myself through it again."
"Teacher was unwilling to spend sometime outside the classroom."
"It wasn't content; it was the teacher."

"I was taught by physics teachers who were really old and boring, super strict."

The nature of physics content and activities

A number of students from the two groups conveyed the impression that physics content and activities in one way or the other impacted their decisions regarding Physics 12 as implied in the statements below:

"Practical questions answered: why and how things work."
"All we did in physics 11 was copy notes and solve text problems. There were no hands-on activities."
"Material was regurgitated from textbooks."
"All we did in physics 11 was copy notes and solve text problems. There were no hands-on activities." (See also the "physics teacher" above),
"Too much note writing and lots of word problems."
"Content was very difficult."
"Previous physics topics involved too much math."
"Physics not really applicable to my life."
"Practical questions answered: why and how things work."
"Hands-on type of activities."
"Physics seemed far removed from real life – "dry"
"General impression that physics was boring, dry, hard and for nerds."

Prior Knowledge and experience

Although the charge that physics teachers assumed a lot regarding the mathematics knowledge the students took to physics classes may be implied in the mathematics factor discussed above, other revelations regarding prior knowledge that we can learn from emerged. Statements such as the following conveyed the effect this had on some of the participants' decisions regarding physics 12:

" I did well in Physics 11."
"There was a rumour that the physics guy was not good."
"Science was my favourite."
" I had difficulties with math."
"I was not a good math student."
"I started failing because of the math since marking was about correct numbers."

Some of these were overwhelmingly prominent as discerned from questionnaire data. . Based on these revelations, three broad questions were formulated for interview sessions with those who had indicated willingness and whose questionnaire responses were very enlightening regarding the question of what attracted some of the participants to or prevented them from majoring in physics. The factors, which featured prominently and around which the items for physics teacher candidates were designed included: *the physics teacher*, *mathematics* and *learning/study styles*. The first two of these factors applied to biology/chemistry teacher candidates. However, the third item for the biology/chemistry group involved the *nature of physics activities*, featured prominently among the teacher candidates.

Interview items for physics teacher candidates:

- *You mentioned in your questionnaire responses that the physics teacher influenced your decision to take physics 12. Tell me more about the teacher*
- *You also mentioned in your questionnaire responses that mathematics in physics prevented your high school colleagues from taking physics 12.Can you elaborate on that?*
- *In your responses to the questionnaire, you mentioned that physics does not have room for too much memorization compared to other science subjects. Can you elaborate on that?*

Interview items for biology/chemistry teacher candidates:

- *In your responses to the questionnaire you mentioned the physics teacher as having influenced your decision not to take physics 12/not to continue with physics.*
  - *Tell me more about how the physics teacher influenced your decision.*
  - What would you have envisioned a model physics teacher to be?
- *You have also mentioned mathematics as playing a major role in your decision not to take physics 12/not to continue with physics.*
  - *Can you say more about this?*
  - *Was there anything the physics teacher could have done to help?*
- *You mentioned lack of appeal to human emotion in physics activities as the reason for not taking physics 12/not continuing with physics.*
  - *Can you elaborate on that?*

Although other factors emerging from the questionnaire responses were not reflected in the core interview questions, they nonetheless surfaced during the interview process. For example, counselors were cited as "wielding" great influence on student's course choices. Three of the interviewees said that counselors influenced students' decisions about Physics12. They revealed that the marks received in each subject were monitored and compared to university requirements. If counselors felt that a certain subject could lower a student's mean score or grade and jeopardize the students' chances of getting into university, then the counselors would advise such a student not to enroll in the subject in which performance was poor. This view resonates with observations highlighted in the Wilson and Rossman (1993) study.

Other revelations included: the factor of gender, teachers' assumptions of students' prior knowledge of mathematics, when quantitative aspects of physics should be introduced, and study skills among others.

Though the gender factor came from only two participants (one male and one female), it is worth learning from. The male interviewee, who was a physics teacher candidate felt that some of the would be female physics majors dropped out of the subject due to the lack of model female physics teachers whom they could emulate:

"Perhaps more positive female teachers could have attracted more girls"

Implicit in this view is the idea that the portion for females was not being filled and may also convey the "blame the victim" type of mentality, which has "silently" pervaded some of the physics classrooms. As if to echo the male participant's view, a female biology/chemistry teacher candidate said:

" [I] could have been encouraged if there were more girls."

This made sense since being the only female student in a male dominated class intimidated her. It takes the teacher's sensitivity and to some extent the female student's courage for such a student to "survive" in such a class. There exists extensive literature regarding issues of gender in science and this paper will not dwell on it (see for example, Rennie, 2000; McGinnis, 2000; Atwater, 2000; Howes, 2000; Brickhouse, 2001). However, the point raised in this study is significant and enlightening – it reveals the fact that the there is under representation of women in physics, a factor that can send mixed messages to would be female physics majors – that physics is not a subject for females.

Another factor linked to the one of mathematics factor is physics teachers' assumptions about students' knowledge of mathematics. It emerged from the discussion that a good physics teacher should also be a good mathematics teacher. Following on this, those who were interviewed expressed the view that it might be useful for physics teachers to minimize the quantitative aspect of physics at the initial stages and ease the students into this aspect starting with remedial lessons on the necessary mathematics for each topic that is perceived to involve calculations. In addition, several teacher candidates suggested the kind of physics and image of physics they would want to see:

"Offer a physics course with less emphasis on calculations, though not a sound foundation for university work in physics"
"Portraying physics as for all and not for socially inept intellectuals"

The issue of study skills came up with contrasting views. Several physics teacher candidates felt memorization has no place in physics.

"Biology had too much memorization"
"It's not possible to memorize."
" It requires understanding.
"

Implicitly, these representative statements seem to imply that those who did not major in physics chose subjects in which facts are memorized. The counter claim came from some biology/chemistry teacher candidates who thought that there were too many facts including formulas to be memorized in physics. They asserted that biology being a human subject comprises facts that do not necessarily have to be memorized, but can be experienced and remembered easily.

"Chemistry and biology had less mathematics and no memorization of formulas"
"Biology and chemistry are more related to real life; physics was about pulleys, levers, and torque – concepts that didn't matter too much in everyday life"

Remembrance in this case appears distinct from memorization, which some physics teacher candidates seemed to equate.

Interviews with some physics teacher candidates revealed a desire to see physics approached differently. This group of candidates felt that some physics teachers have the habit of introducing the mathematical aspect rather too early. Their view was that conceptual physics should precede the quantitative aspect of physics, which should be introduced gradually- i.e., emphasizing conceptual understanding as the students are eased into the quantitative (mathematical) aspect before engaging them into full blown mathematical relationships and problem solving. Two of the physics teacher candidates interviewed further suggested that it might make things easier (better) if physics teachers identified the necessary mathematical tools for the appropriate topics and prepare respective remedial lessons as a way of ensuring that their students have the requisite tools to understand the intended physics topics/concepts.

One of the physics teacher candidates felt that physics was being introduced too late (in grade 11) in high school as a subject. He suggested that it should be introduced right from senior elementary classes:

"Introducing the physics subject from senior elementary classes. Introducing physics in grade 11and 12 is counter productive."

When reminded of the fact that physics topics are already part of the grade 7, 8, 9 and 10 science curriculum, he responded by saying that

> "Physics is a stigmatized subject and it should be accorded the prominence that subjects like mathematics are receiving. Introducing [it earlier] would prepare the students to appreciate the fact that physics is not just mathematics, but has other non -mathematical components."

Of course this candidate had a very important point to make. Such a curriculum organization could even advantage students in the sense that they may recognize the usefulness of mathematics early enough and might in turn improve their overall performance in mathematics.

The inferences described below have been drawn from the questionnaire and interview data corpus, and are considered representative and illustrative of the key factors likely to be impacting high school students' decisions about Physics 12 in BC.

Inferences

Several points emerged from the study in the form of inferences, which are considered significant to the inquiry question and the preparation of preservice physics teachers as well as the teaching of physics in general. These include:

Mathematics as a very important tool in physics.

The majority of the teacher candidates from both groups underscored the value of mathematics in physics, with some almost equating physics to mathematics. Others have implicitly described physics as though it were another branch of mathematics. Justifiably, they convey the picture of some high school instructors, who right from the start introduce physics concepts mathematically. This is not to negate the central role mathematics plays in physics, but rather to underscore its unique relationship with physics. Perhaps because of mathematics' inseparable relationship with physics, shouldn't physics teachers provide special remedial in the necessary mathematics before engaging them in say, formula derivations, calculations, etc?

The physics teacher as one who can inspire or create resentment in potential physics majors.
From the data, the teacher is portrayed as inspiring or uninspiring. Instructional styles and how the physics teacher relates to the subject he/she teaches impacts students' subject choices. In this connection, motivation of students who "try" is crucial.

Physics content and activities portrayed as "dry"

Many chemistry/ biology teacher candidates have described physics content and activities as "dry". Again this seems to point back to "the physics teacher". The nature of activities is important to the way students perceive their future position in the subject. The participants from both groups underscored the importance of the hands-on activity approach. One of the female participants revealed that she did not continue with physics due the problems she experienced in mechanics. Perhaps teachers need to reorganize their curriculum planning, organization and implementation, say, from the current UNIT approach to the SPIRAL approach – where concepts are developed spirally from one grade level to another.

Gender as a significant factor in high school students' subject/course choices

One male physics teacher candidate implied in his responses that perhaps the shortfall in the Physics 12 enrolment is because the girls' portion is not filled. In the same vein, a female chemistry/biology teacher candidate explicitly said the fact that she was the only female student in her Physics 11 class intimidated her. Again, a teacher who is gender sensitive can reverse a situation like this. There can never be enough model female physics teachers without this "single girl" being retained in physics.

These inferences represent a summarized analysis of the data collected on the perspectives of UBC science teacher candidates. By implication, the factors discerned can convey the image of the status of Physics 12 in BC. Reflecting on them (views), can provide a preservice teacher with a sensitivity that is required if the attempt to change the current status of low enrolments in Physics 12 is to be alleviated. Discussion of some of the factors, which have emerged from the current study and what they mean to physics teacher education programs and instruction is one way to bring about the necessary consciousness in the physics teaching, hoping that more high school students will be attracted to majoring in physics. After all, according to Blanton (2003):

> Many people who become teachers, resort to teaching in the same manner they were taught (typically traditional transmission lectures) They were successful at learning in this manner. It's the method of instruction that has been "modeled" for them (p.125).

Therefore, it is also for this reason that preservice teachers should reflect on their own high school physics learning experience with the hope that, if their instructors made errors, then they should be avoided at all cost.

Implications for physics teaching

Valuing the knowledge students bring to classrooms creates dilemmas in many science teachers, especially physics teachers - whether they should just accept everything the students say or not. If not, the question that arises is at what stage should they reject the scientifically unacceptable ideas? Surely, this should not be a question of rejecting, but one of how to bring about change in a way that can enable students to conceptualize things in ways acceptable to science – changing to the way physics requires things to be seen. And bringing about this change constitutes bringing about sort of what Kuhn (1970) describes as undergoing a paradigm shift– understanding things in a new way – one that is different from the pre-instruction understanding. Posner et al. (1982) point out the necessary conditions for bringing about the change: plausibility, intelligibility and usefulness of the new ideas. In other words, it is through a method of providing opportunities for students to encounter reality that meaningful meaning of encounters is made:

This ... encounter with reality helps students evaluate the accuracy of their "knowledge" as they explain the reasons for their interpretations of the results. For this method to be successful students must be equipped with the tools to help them make accurate [interpretations] (Blanton, 2003, p.125).

In this case, the nature of lesson activities matters greatly. Discrepant events have proved of worth in eliciting students' preconceptions and readying them for conceptual change – creating in them a state of conceptual conflict. Gunstone (1994) has suggested a "Predict – Explain – Observe" (PEO) strategy that involves asking students to predict outcomes of events, which they have to justify before being given the opportunity to experiment and make observations. Usually the observations are in conflict with the predictions, thus forcing the students to search for alternative explanations. Explaining predictions most likely reveals frameworks that inform students' interpretations of new events (Driver, 1989; Kelly, 1955).

PEO activities are meant to challenge alternative frameworks. In other words, students must find pre-experience knowledge inadequate to explain experimental observations. Therefore, the question here is whether or not physics teachers are equipped with the skills and awareness of designing effective PEO activities, which in most cases are time consuming. Nonetheless, for the sake of good pedagogy, the moment becomes opportune for the teachers to allow students to make their understandings known and in turn present them with experiences that challenge their preconceptions - initiating new conceptualization or conceptual change.

On the one hand, the culture, which sometimes portrays physics as a subject for the gifted few and difficult, can be viewed with contempt and as "tyrannical" by the majority of the students who are prevented from majoring in it by teachers complacent with the discriminatory conducts – for example, using too much mathematics irrespective of students' inadequacies at the mathematics. On the other hand, the teachers who create friendly learning environments – those who initially accept students' alternative ideas and in meaningful and systematic ways provide counter experiences, and in systematic ways provide remedial lessons in the appropriate mathematical concepts for use in physics, have higher chances of attracting more students into majoring in physics. In addition, teaching the history and philosophy of science can contribute to the process of humanizing science teaching (Matthews, 1994, 2000). Of course, physics teaching can benefit from this approach as well.

Physics teaching like any other teaching is about helping those from beyond its borders to cross over to the physics culture. In this case, helping high school students to cross the borders between physics and other science subjects (Aikenhead, 1996; Giroux, 1992; Giroux & Maclaren, 1994), and between physics and other non-science subjects – of course, the aim being to have them cross over to physics. Jegede (1995), while recognizing the idea of border crossing, points out the ability of some students to operate in more than one framework (paradigm), a phenomenon he calls collateral learning. These frameworks are a consequence of multicultural affiliations, which Solano-Flores and Nelson-Barber (2001) say must be considered when carrying out authentic assessments – only possible if ways of eliciting students' prior knowledge are utilized. Assessment is in a way a powerful tool for enforcing learning if the items are deliberately set to do just that. In fact, Lawton and Gordon (1978) have indicated the useful nature of assessment in enforcing curriculum innovation, provided it is not used as a way of judging teachers' ability to teach to the exam.

Ignoring the effect of socio-cultural affiliations, which probably is the case in physics teaching, may "shut out" many potential physics majors. Claxton (1993) refers to these affiliations as "stances", which students take due to the multiple allegiances they pledge to various social groups. These allegiances influence what such students do, say and even accept as science or physics knowledge. This most likely impacts the way such students view physics classes. Depending on the group to which the students owe strong allegiance, the teacher may find very few of them majoring in physics as a consequence of collective or group resolutions.

In a way, Bruner (1996) seems to reiterate the importance of cultural settings and resources in planning instruction – cultural settings and resources are in part prerequisites in understanding the mental activity because of the role they play in giving the mind the shape and scope. But teachers' beliefs, which Lumpe, Haney and Czerniak (2000) categorize as context, capability and personal agency, also determine the way science and for that matter physics teachers run their classes. As practitioners (Schon, 1983), teachers need to reflect not just on classroom teaching but also on what it is that can "shut out" certain groups of students who have the potential to cross the border around physics to become physics majors.

Reflective practice (Schon, 1983), in part, involves understanding how one's (a teacher's) actions might impact others' (students') decisions about future choices.

Suggestions

Though still evolving, the following School Physics Instruction Model (SPIM) is proposed as a tool for physics teaching. It takes into consideration some of the key instructional factors raised, and embraces some constructivist ideals (Driver, 1989; Gunstone, 1994).

The SPIM

The proposed "School Physics Instruction Model" (SPIM) comprises seven steps of planning and implementing physics instructions:

1. *Elicit students' prior knowledge of topic*

   This seems pedagogically in order. Research has continued to underscore the role of prior knowledge in new knowledge construction (Driver, 1989).

2. *Identify students' counter physics preconceptions*

   Not all prior knowledge is acceptable in physics. Therefore, identifying students' prior counter physics ideas about a topic intended for instruction alerts the physics teacher to undesirable preconceptions in order to plan a challenge.

3. *Plan practical activities challenging counter physics conceptions*

   The best pedagogical approach to confront counter physics preconceptions is to prove the inadequate by providing experiences in which the ideas get challenged. Targeting such ideas by presenting to the students experiences that may likely cause cognitive conflict and put students in a state of anxiety to search for more meaningful explanations to the discrepant events, consistent with Posner et al. (1982) model that spells out conditions necessary for conceptual change.

4. *Qualitatively discuss the activity findings as a prerequisite to developing mathematical models*

   This arises from the concern expressed by some participants in the current study regarding the casual manner in which physics teachers treat students' prior mathematical knowledge. In other words, there is some sense in starting with qualitative aspects, while realizing that in some cases quantitative and the qualitative aspects are intertwined and difficulty to separate. However, a deliberate effort should be made to progressively move from qualitative to the integration of both qualitative and quantitative aspects.

5. *Identify key mathematical concepts within the topic and provide remedial lessons*

   Mathematics is considered part of a students' prior knowledge in this paper since it is a tool of physics. Studies have shown how the majority of students are put off by the mention of mathematics related terminology in physics. This inevitably calls for a deliberated effort during planning and implementation of physics instructions to provide remedial lessons in the appropriate mathematics concepts for use in the physics class. In other words, "sharpen the tool " before use.

6. *Progressively ease the students into the quantitative aspects of the topic.*

   Easing students into the quantitative aspects of physics is probably one way of ensuring that students see the link between the ideas they learn in mathematics classes and the application of the same in physics. Furthermore, one does not want a situation whereby the mathematics being used obscures the understanding of the intended physics concepts.

7. *Provide application problems and questions for practice.*

   Application of any ideas to real life situation is one way of ensuring relevance, mastery and meaningfulness on a personal level. And, practice is many times a sure way of developing proficiency and competency.

These seven steps or stages provide the minimum requirements for planning and implementing instructions, whose success may also depend on a variety of other factors outside the scope of this paper.

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